

V.3.3-SS-SAC STATE SPACE SACRAMENTO MODEL OPERATION

Identifier: SS-SAC

Application: Operational Forecast System programs only

Description: This Operation uses observed mean areal precipitation or rain-plus-melt, mean areal evapotranspiration demand and discharge time series data and a modified version of the Sacramento soil moisture accounting model that includes a channel-routing component to forecast stream flow discharge.

The Operation is based upon the model documented in IIHR Technical Report Number 325 by Georgakakos, Rajaram and Li (1988) and in the HRC Technical Report Number 1 by Sperfslage and Georgakakos (1996).

Using user-supplied degree-of-belief estimates for the variance of Sacramento model parameters and of forecast evapotranspiration demand and precipitation or rain-plus-melt input to the Sacramento model, it also performs real time updating of Sacramento and channel-routing model storage elements from observations of discharge, and provides discharge forecast-error variance information. Missing values in the observed discharge time series are accommodated. Sacramento model modifications were made to facilitate the stable computation of derivatives for the covariance propagation and updating components of the operation. The covariance equations are coupled with the Sacramento and channel-routing model equations for robust performance under a variety of data time intervals. The Channel model component is a conceptual kinematic channel routing model consisting of a series of nonlinear or linear reservoirs. In the latter case, the unit hydrograph coordinates may be used to estimate the channel-routing model parameters as described in Sperfslage and Georgakakos (1996).

Several provisions are included in this model:

1. Evapotranspiration data can be supplied as either:
 - o potential evapotranspiration time-series values along with twelve monthly correction factors used to convert the potential values to actual evapotranspiration demand or
 - o long-term mean monthly actual evapotranspiration demand values
2. Runs can be one of three types with respect to timing:
 - o the entire run is in the past (no forecast); $LDACPD \geq LDA$
 - o the entire run is in the future (no updating except from carryover); $LDACPD < IDA$
 - o there is both updating and forecasting; $IDA \geq LDACPD < LDA$

3. The User specifies the coefficient of variation of the forecast input precipitation or rain-plus-melt in one of the following ways:
 - o as a constant for all forecast time periods as part of the PIN routine
 - o as an input time series of modifiers for the coefficient of variation, one for each forecast time interval, with data type DFAC

The latter option is only recommended when the User is confident that the default constant value is incorrect for the particular storm forcing situation at hand. Negative values for the DFAC modifiers are set to 1 and a warning message is printed. In this document these modifiers are also referred to as MAP variance modifiers.

The number of soil parameters is set to 18.

The first soil parameter is set to 1.0.

The last 3 soil parameters are set to 8.0.

References:

Georgakakos, K., Rajaram, H. and S.G. Li, 1988: On Improved Operational Hydrologic Forecasting of Streamflows. IIHR Technical Report No. 325. Iowa Institute of Hydraulic Research, The University of Iowa, Iowa City, Iowa, 52242, 162 pp.

Sperfslage, J.A., and K.P. Georgakakos, 1996: Implementation and Testing of the HFS Operation as Part of the National Weather Service River Forecast System (NWSRFS). HRC Technical Report No. 1. Hydrologic Research Center, San Diego, California, 92130, 213 pp.

Developed By: Hydrologic Research Center

Allowable Data Time Intervals: 1, 2, 3, 4, 6, 8, 12 and 24 hours

Time Series Used: Time series used in this Operation are as follows:

<u>General Type</u>	<u>Dimn</u>	<u>Units</u>	<u>Use</u>	<u>Required</u>	<u>Form of Output T.S.</u>	<u>Data Time Interval</u>	<u>Missing Values Allowed</u>
Precipitation	L	CM	I	yes	n/a	any	no
Potential ET	L	CM	I	yes	n/a	any <u>1/</u>	no
Discharge	L3/T	CMS	I	yes	n/a	any <u>2/</u>	yes

Simulated Discharge	L3/T	CMS	0	no	estimated/ predicted <u>3/</u>	any <u>2/</u>	n/a
Simulated Discharge Standard Deviation	L3/T	CMS	0	yes	estimated/ predicted <u>3/</u>	any <u>2/</u>	n/a
MAP Variance Modifiers	DLES	n/a	I	yes	n/a	any <u>2/</u>	no

1/ Must be a multiple of the precipitation interval.

2/ Must be the same as the precipitation interval.

3/ Updated discharge saved at computational time steps,
Predicted discharge saved at forecast steps.

Input Summary: The card input for this Operation is as follows:

<u>Card</u>	<u>Format</u>	<u>Columns</u>	<u>Contents</u>
1	15A4	1-60	General heading for parameters
2	2A4,2X	1-10	Internal identifier for the precipitation time series
	2A4,2X	11-20	Internal identifier for the ET time series (disregarded if ETSW=0)
	2A4,2X	21-30	Internal identifier for the discharge time series
	2A4,2X	31-40	Internal identifier for the simulated discharge time series
	2A4,2x	41-50	Internal identifier for the simulated discharge standard deviation time series
	2A4	51-58	Internal identifier for the MAP variance modifier time series
3	A4,2X	1-6	Data type code for precipitation time series
	A4,2X	7-12	Data type code for ET time series (disregarded if ETSW=0)
	A4,2X	13-18	Data type code for discharge time series
	A4,2X	19-24	Data type code for simulated discharge time series
	A4,2x	25-30	Data type code for simulated discharge standard deviation time series

<u>Card</u>	<u>Format</u>	<u>Columns</u>	<u>Contents</u>
	A4	31-34	Data type code for time series of MAP variance modifiers
4	I5	1-5	ET time series interval (disregard if ETSW=0)
5	I5	1-5	Computational time interval; time interval for precipitation, observed discharge and simulated discharge time series
	I5	6-10	Flag ETSW for use of ET time series. If ETSW: 1 = if potential ET time series used and the twelve monthly correction factors are to be read 0 = if no ET time series are used and the twelve monthly actual ET demand values are to be read
6	7E10.3	1-70	Monthly ET values for January-July, each to the 16th of the particular month. If ETSW: 1 = these are average daily correction factors 0 = these are long-term average, monthly actual demands
7	5E10.3	1-50	The rest of the monthly ET values for August-December
Soil parameters:			
8	E10.3	1-10	UZTWM (upper zone tension water capacity, MM)
	E10.3	11-20	UZFWM (upper zone free water capacity, MM)
	E10.3	21-30	LZTWM (lower zone tension water capacity, MM)
	E10.3	31-40	LZFPW (lower zone primary free water capacity, MM)
	E10.3	41-50	LZFSM (lower zone supplemental free water capacity, MM)
	E10.3	51-60	UZK (fractional daily upper zone free water withdrawal rate)
	E10.3	61-70	LZPK (fractional daily primary withdrawal rate)

<u>Card</u>	<u>Format</u>	<u>Columns</u>	<u>Contents</u>
9	E10.3	1-10	LZSK (fractional daily supplemental withdrawal rate)
	E10.3	11-20	ZPERC ((ZPERC+1)*PBASE is the maximum percolation rate)
	E10.3	21-30	REXP (exponent for the percolation equation)
	E10.3	31-40	PFREE (percent/100 of percolated water which always goes directly to lower zone free water storages)
	E10.3	41-50	SIDE (ratio of non-channel baseflow (deep recharge) to channel (visible) baseflow)
	E10.3	51-60	ADIMP (additional impervious area - percent/100)
	E10.3	61-70	PCTIM (minimum impervious area - percent/100)
10	E10.3	1-10	Catchment area, square kilometers
11	I5	1-5	Number of routing reservoirs (NR)
Reservoir parameters:			
12	E10.3	1-10	XM (exponent of generic non-linear routing reservoir)
	E10.3	11-20	ALP (coefficient of generic non-linear routing reservoir)
Variance parameters:			
13	E10.3	1-10	Coefficient of variation of mean areal precipitation
	E10.3	11-20	Constant standard deviation of mean areal precipitation
14	E10.3	1-10	Coefficient of variation of mean areal ET demand
	E10.3	11-20	Constant standard deviation of mean areal ET demand
15	E10.3	1-10	Constant standard deviation of discharge
	E10.3	11-20	Coefficient of variation of discharge
16	E10.3	1-10	Coefficient of input component of model-

<u>Card</u>	<u>Format</u>	<u>Columns</u>	<u>Contents</u>
			error covariance
	E10.3	11-20	Coefficient of parameter component of model-error covariance

Standard deviation of parameter estimates:

17	E10.3	1-10	For soil parameter UZTWM
	E10.3	11-20	For soil parameter UZFWM
	E10.3	21-30	For soil parameter LZTWM
	E10.3	31-40	For soil parameter LZFPM
	E10.3	41-50	For soil parameter LZFSM
	E10.3	51-60	For soil parameter UZK
	E10.3	61-70	For soil parameter LZPK
18	E10.3	1-10	For soil parameter LZSK
	E10.3	11-20	For soil parameter ZPERC
	E10.3	21-30	For soil parameter REXP
	E10.3	31-40	For soil parameter PFREE
	E10.3	41-50	For soil parameter SIDE
	E10.3	51-60	For soil parameter ADIMP
	E10.3	61-70	For soil parameter PCTIM
19	E10.3	1-10	For reservoir parameter ALP
	E10.3	11-20	For reservoir parameter EXP

Soil initial carryover means (MM):

20	E10.3	1-10	For UZTWC (upper zone tension water contents)
	E10.3	11-20	For UZFWC (upper zone free water contents)
	E10.3	21-30	For LZTWC (lower zone tension water contents)
	E10.3	31-40	For LZFPC (lower zone primary free contents)
	E10.3	41-50	For LZFSC (lower zone supplemental free

<u>Card</u>	<u>Format</u>	<u>Columns</u>	<u>Contents</u>
			contents)
	E10.3	51-60	For ADIMC (additional impervious contents). If not known, use ADIMC = UZTWC + LZTWC.
Initial conditions for covariance matrix diagonal elements:			
21	E10.3	1-10	Soil water storage element #1
	E10.3	11-20	Soil water storage element #2
	E10.3	21-30	Soil water storage element #3
	E10.3	31-40	Soil water storage element #4
	E10.3	41-50	Soil water storage element #5
	E10.3	51-60	Soil water storage element #6
	E10.3	61-70	Reservoir water storage element #1
22	E10.3	1-10	Remaining m elements (NR - 1 where NR must be less than or equal to 6)
23	E10.3	1-10	Initial discharge observed data (in CMS)

Sample Input and Output: Sample input is shown in Figure 1. Sample output from the parameter print routine is shown in Figure 2.

During execution this Operation prints a row of values that appears at each computational time interval. Each row list the following parameters:

- o observed precipitation (MM/timeint)
- o observed actual ET demand (MM/timeint)
- o predicted discharge (MM/timeint)
- o predicted discharge standard deviation (MM/timeint)
- o observed discharge (MM/timeint)
- o updated discharge (MM/timeint)

where timeint is the computational time interval

A sample of the execution routine output for 40 computational steps and 12 forecast steps is shown in Figure 3.

Error and Warning Messages: The error and warning messages generated by this Operation and the corrective action to take when they occur follow.

- A. Messages that can occur during setup (the variable Pold represents the input parameter that is unacceptable and Pnew

represents the new value of the variable as changed):

1. ****ERROR**** COMPUTE TIME INTERVAL= Pold BUT ONLY INTERVALS OF 1,2,3,4,6,8,12 AND 24 ARE ALLOWED.

Cause: Invalid computation interval.

Action: Change the input file for a parameter value which divides evenly into 24.

2. ****ERROR**** ET DATA INTERVAL= Pold IS NOT A MULTIPLE OF THE COMPUTE TIME INTERVAL.

Cause: Invalid potential ET time series data interval.

Action: Change the input file for a parameter value which is a multiple of the compute time interval.

3. ****ERROR**** ET CORRECTION FACTOR# month# = Pold CANNOT BE NEGATIVE.

Cause: When using potential ET time series data, a monthly correction factor less than zero was read.

or

****ERROR**** ET DEMAND VALUE# month# = Pold CANNOT BE NEGATIVE.

Cause: When using monthly actual ET demand data, a monthly value less than zero was read.

Action: Change the input file for a parameter value for month# which is greater than or equal to zero.

4. ****WARNING**** SACRAMENTO MODEL PARAMETERS WERE CHANGED BECAUSE THEY WERE ASSIGNED IMPOSSIBLE VALUES. Pold : changed to Pnew

Cause: An impossible value was read for one or more soil parameters. The parameter restrictions are:

UZTWM, UZFWM, LZTWM, LZFPM and LZFSM .GE. 0.1
UZK, LZPK, LZSK, PCTIM and PFREE .LE. 1.0
ZPERC and REXP .GE. 1.0E-04
SIDE .GE. 0.0
ADIMP .LE. (1.0 - PCTIM)

Action: Either change the input file for a parameter value which is within above limits or continue using the new value shown above.

5. ****ERROR**** CATCHMENT AREA CANNOT BE .LE. 0.

Cause: A negative value was read for catchment area.

Action: Change the input file for a parameter value greater than 0.

6. ****WARNING**** NUMBER OF RESERVOIRS WAS CHANGED FROM Pold TO Pnew.

Cause: The number of routing reservoirs read was either less than 1 or greater than 6.

Action: Either change the input value to between 1 and 6 the or continue using the Pnew value shown.

7. ****WARNING**** ROUTING RESERVOIR EXPONENT PARAMETER CHANGED FROM Pold TO Pnew

Cause: Routing reservoir exponent read was either less than 0.5 or greater than 2.

Action: Either change the input file for a parameter value within the above limits continue using the value shown.

8. ****WARNING**** ROUTING RESERVOIR COEFFICIENT PARAMETER CHANGED FROM Pold TO Pnew

Cause: Routing reservoir coefficient parameter read was less than 0.01.

Action: Either change the input file for value within the above limits continue using the value shown.

9. ****WARNING**** MAP COEF OF VARIATION VARIANCE PARAMETER WAS CHANGED FROM Pold TO Pnew

Cause: MAP coefficient of variation variance parameter read was either less than 0 or greater than 5.

Action: Either change the input file for a value within the above limits continue using the value shown.

10. ****WARNING**** MAP CONSTANT STANDARD DEVIATION VARIANCE PARAMETER WAS CHANGED FROM Pold TO Pnew

Cause: MAP constant standard deviation variance parameter read was less than 0.01.

Action: Either change the input file for a value within the above limits continue using the value shown.

11. ****WARNING**** ET COEF OF VARIATION VARIANCE PARAMETER WAS CHANGED FROM Pold TO Pnew

Cause: ET coefficient of variation variance parameter read was either less than 0 or greater than 5.

Action: Either change the input file for a value within the above limits continue using the value shown.

12. ****WARNING**** ET CONSTANT STANDARD DEVIATION VARIANCE
PARAMETER WAS CHANGED FROM Pold TO Pnew

Cause: ET constant standard deviation variance parameter
read was less than 0.01.

Action: Either change the input file for a value within the
above limits continue using the value shown.
13. ****WARNING**** DISCHARGE COEF OF VARIATION VARIANCE PARAMETER
WAS CHANGED FROM Pold TO Pnew

Cause: Discharge coefficient of variation variance
parameter read was either less than 0 or greater than 5.

Action: Either change the input file for a value within the
above limits continue using the value shown.
14. ****WARNING**** DISCHARGE CONSTANT STANDARD DEVIATION VARIANCE
PARAMETER WAS CHANGED FROM Pold TO Pnew

Cause: Discharge constant standard deviation variance
parameter read was less than 0.01.

Action: Either change the input file for a value within the
above limits continue using the value shown.
15. ****WARNING**** COEF OF INPUT COMPONENT OF MODEL-ERROR
COVARIANCE CHANGED FROM Pold TO Pnew

Cause: Coefficient of input component of model-error
covariance read was less than 0.01.

Action: Either change the input file for a value within the
above limits continue using the value shown.
16. ****WARNING**** COEF OF PARAMETER COMPONENT OF MODEL-ERROR
COVARIANCE CHANGED FROM Pold TO Pnew

Cause: Coefficient of parameter component of model-error
covariance read was less than 0.01.

Action: Either change the input file for a value within the
above limits continue using the value shown.
17. ****WARNING**** STANDARD DEVIATION OF MODEL PARAMETER ESTIMATE
WAS CHANGED FOR: parameter name FROM Pold TO Pnew

Cause: An impossible value was read for one or more
standard deviation of soil model parameter estimates. Each
standard deviation must be both greater than 1.E-8 and less
than or equal to 3 times its corresponding soil parameter.

Action: Either change the input file so that the specified
parameter values are within their limits or continue using
the values shown.

18. ****WARNING**** STANDARD DEVIATION OF ROUTING RESERVOIR EXPONENT PARAMETER WAS CHANGED FROM Pold TO Pnew

Cause: An impossible value was read for the standard deviation of the routing reservoir exponent estimate. It must be both greater than 1.E-8 and less than or equal to three times its corresponding reservoir parameter.

Action: Either change the input file for a parameter value which is within the above limits or continue using the values shown.

19. ****WARNING**** STANDARD DEVIATION OF ROUTING RESERVOIR COEFFICIENT PARAMETER WAS CHANGED FROM Pold TO Pnew

Cause: An impossible value was read for the standard deviation of the routing reservoir coefficient estimate. It must be both greater than 1.E-8 and less than or equal to three times its corresponding reservoir parameter.

Action: Either change the input file for a parameter value which is within the above limits or continue using the values shown.

20. ****WARNING**** INITIAL STATE VARIABLES CONTAIN IMPOSSIBLE VALUES AND WERE CHANGED.

INITIAL: Pold
CHANGED: Pnew

Cause: An impossible initial soil state was read. Each state mean must be greater than or equal to 0 or it will be set to 0. In addition, states 1-5 must each be less than or equal to its corresponding capacity parameter and state 6 (ADIMC) must be less than or equal to LZTWM. or the state will be set to the corresponding parameter.

Action: Either change the input file so that the value for each state is within its corresponding limit or continue using the values shown.

21. ****WARNING**** DIAGONAL ELEMENTS OF INITIAL STATE COVARIANCE MATRIX CONTAIN IMPOSSIBLE VALUES AND WERE CHANGED:

INITIAL: Pold
CHANGED: Pnew

Cause: A diagonal element of the initial state covariance matrix was read with either a value less than 1.E-8 or for soil elements a value greater than three times its corresponding state mean.

Action: Either change the input file for parameter values which are within above limits or continue using the values shown.

22. ****ERROR**** INITIAL DISCHARGE PARAMETER CANNOT BE NEGATIVE.

Cause: The initial discharge value read was less than zero.

Action: Change the input file for a parameter value greater than zero.

23. ****ERROR**** PIN22 NEEDS nnnnn WORDS IN P ARRAY, BUT ONLY nnnnn ARE AVAILABLE.

Cause: There is not enough space available in the FC parameter array to contain the parameters for this Operation.

Action: Call your Focal Point.

24. ****ERROR**** PIN22 NEEDS nnnnn WORDS IN C ARRAY BUT ONLY nnnnn ARE AVAILABLE.

Cause: There is not enough space available in the carryover array to contain the carryover from this Operation.

Action: Call your Focal Point.

25. ****ERROR**** data type code PRECIPITATION DATA TYPE IS INVALID.

Cause: The precipitation data type is not properly defined. The data type code was used for the check but no time series for it exists.

Action: Change the input file for correct type code.

26. ***ERROR*** [time_series_identifier] PRECIPITATION TIME SERIES HAS NOT BEEN PROPERLY DEFINED.

Cause: The precipitation time series is not properly defined. Either the time series identifier is wrong, the time series interval is invalid, the time-series has missing values or there is more than 1 data value stored per time interval.

Action: Change the input file for correct time series identifier or interval.

27. ****ERROR**** data type code DISCHARGE DATA TYPE IS INVALID.

Cause: The discharge data type is not properly defined. The data type code was used for the check but no time series for it exists.

Action: Change the input file for correct type code.

28. ***ERROR*** [time_series_identifier] DISCHARGE TIME SERIES HAS NOT BEEN PROPERLY DEFINED.

Cause: The discharge time series is not properly defined. Either the time series identifier is wrong, the time series interval is invalid, (same interval as for precipitation data is used) or there is more than 1 data value stored per

time interval.

Action: Check the above conditions and if necessary change the input file for correct time series identifier.

29. **ERROR** data type code SIMULATED DISCHARGE DATA TYPE IS INVALID.

Cause: The Simulated Discharge data type is not properly defined.

Action: Change the input file for correct type code parameter. The data type code was used for the check but no time series for it exists.

30. *ERROR* [time_series_identifier] SIMULATED DISCHARGE TIME SERIES HAS NOT BEEN PROPERLY DEFINED.

Cause: The simulated discharge time series is not properly defined. Either the time series identifier is wrong, the time series interval is invalid, (same interval as for precipitation and discharge data) or there is more than 1 data value stored per time interval.

Action: Check the above conditions and if necessary change the input file for correct time series identifier.

31. **ERROR** data type code SIMULATED DISCHARGE STDEV DATA TYPE IS INVALID.

Cause: The Simulated Discharge Stdev data type is not properly defined. The data type code was used for the check but no time series for it exists.

Action: Change the input file for correct type code parameter.

32. *ERROR* [time_series_identifier] SIMULATED DISCHARGE STDEV TIME SERIES HAS NOT BEEN PROPERLY DEFINED.

Cause: The Simulated Discharge Stdev time series is not properly. Either the time series identifier is wrong, the time series interval is invalid, (same interval as for precipitation and discharge data) or there is more than 1 data value stored per time interval.

Action: Check the above conditions and if necessary change the input file for correct time series identifier.

33. **ERROR** data type code MAP VARIANCE MODIFIERS DATA TYPE IS INVALID.

Cause: The MAP variance modifiers data type is not properly defined. The data type code was used for the check but no time series for it exists.

Action: Change the input file for correct type code parameter.

34. *ERROR** [time_series_identifier] MAP VARIANCE MODIFIERS TIME-SERIES HAS NOT BEEN PROPERLY DEFINED.

Cause: The MAP variance modifiers time series is not properly defined. Either the time series identifier is wrong, the time series interval is invalid, (same interval as for precipitation and discharge data) or there is more than 1 data value stored per time interval.

Action: Check the above conditions and if necessary change the input file for correct time series identifier.

35. **ERROR** [data_type_code] EVAPORATION DATA TYPE IS INVALID.

Cause: The potential ET data type is not properly defined. The data type code was used for the check but no time series for it exists.

Action: Change the input file for correct type code parameter.

36. **ERROR** [time_series_identifier] EVAPORATION TIME SERIES HAS NOT BEEN PROPERLY DEFINED.

Cause: The potential evapotranspiration time series is not properly defined. Either the time series identifier is wrong, the time series interval is invalid, there is missing data or there is more than one data value stored per time interval.

Action: Check the above conditions and, if necessary, change the input file for correct time series identifier or interval.

37. **ERROR** PIN22 INPUT ERROR nnn ENCOUNTERED IN IOSTMT iostmt, SEE LISTING.

Cause: A FORTRAN file input error was encountered in the statement labeled iostmt.

The input routine loads the parameter array with what is probably the wrong value for the parameters read and then continues.

Action: Call your Focal Point.

B. Messages that can occur during execution:

1. **WARNING** POSSIBLE PROBLEMS DUE TO VERSION CONFLICT!
PIN22 VERSION xx WAS USED TO INPUT PARAMETERS, BUT EX22
VERSION yy IS IN USE.

The version numbers of the PIN22 subroutine (used to input the parameters in use) and EX22 subroutine do not agree. This can happen when either routine is modified and its version number is updated, but the other routine is not modified accordingly.

The routine will continue to execute, but unpredictable results can occur if the modifications to one routine require corresponding modifications in the other.

Action: Call your Focal Point.

2. ****WARNING**** requested number FORECAST STEPS HAVE BEEN REQUESTED, BUT ONLY THE PROGRAM MAXIMUM OF current capacity WILL BE DONE.

Cause: More forecast steps have been specified (forecast interval/time step) than the program array dimensions, etc can handle.

The routine will continue to execute, but will only do the number of forecast steps shown.

3. ****WARNING**** LARGE M.A.P. READ FOR TIME STEP#:
time step index
mon/day/yr hr:00

CURRENT VALUE OF DATAold WILL BE CHANGED TO PRECIPmax

Cause: An extremely large precipitation time series value was encountered.

The Operation will continue executing, but use the current maximum allowed precipitation value (shown above) for this time step.

4. ****WARNING**** INTEGRATION RESULTS MAY BE INACCURATE FOR TIME STEP#:
time step index
mon/day/yr hr:00
CURRENT VALUE OF SUBS PARAMETER = Pold
RERUN WITH SUBS = Pnew

Cause: Numerical difficulties with the prediction routine PRED22. The calculation cannot converge.

Action: Either let the Operation continue and carefully check the prediction at the above time step or increase by 2 the minimum allowable value for SUBS.

5. ****WARNING**** MAP VARIANCE MODIFIERS TYPE IS INVALID FOR TIME STEP#:
time step index
mon/day/yr hr:00
MODIFIER VALUES WILL BE CHANGED TO 1.0

Cause: Invalid specification of the MAP variance modifiers time series.

Action: Change input file to correct data type (DFAC).

6. ****WARNING**** NEGATIVE MAP VARIANCE MODIFIER FOR TIME STEP#: time step index
mon/day/yr hr:00
ORIGINAL VALUE OF -X.XXXE+XX WILL BE CHANGED TO 1.0

Cause: Invalid specification of modifier value.

Action: Verify specification of modifier time series and any runtime MODs that change them.

Carryover Transfer Rules: The following rules apply to the state mean variables and the state covariance matrix elements, for both soil and reservoir carryover. Cold contains old soil and reservoir carryover. Cnew will contain, at the start of the carryover transfer routine, the initial-conditions carryover corresponding to the new set of input parameters and may or may not be replaced with adjusted carryover, as described below.

1. Soil contents deficit adjustment:

If one of the six soil capacity parameters is changed, then the corresponding state variable is adjusted as follows:

$$C_{new} = (C_{old}/P_{old}) * P_{new}$$

where Pold is the parameter value in effect when carryover Cold was saved
Pnew is the new parameter value to use
Cnew is the adjusted carryover to reflect new parameter

The following lists each soil contents state carryover and its corresponding capacity parameter:

UZTWM UZTWC
UZFWM UZFWC
LZTWM LZTWC
LZFPM LZFWC
LZFSM LZFWC
LZTWM ADIMC

2. Catchment area changes, number of routing reservoirs unchanged:

In this case, both soil and reservoir carryover will be adjusted according to the following steps:

- a. Adjust all state means. These are, for soil, the first six deficit-adjusted values and, for routing, the next NR values in the carryover array. They are adjusted as follows:

CNEW = (AREA_NEW / AREA_OLD) * COLD

- b. Adjust covariance matrix variances. These are the (6+NR) diagonal elements of the matrix. The (I,I)th element is adjusted as follows:

```
STDEVOLD = SQRT(COLD(I,I))
STDEVNEW = (AREA_NEW / AREA_OLD) * STDEVOLD
CNEW(I,I) = STDEVNEW * STDEVNEW
```

- c. Adjust the covariance matrix covariances. These are the off-diagonal elements of the matrix. The (I,J)th element of the matrix is adjusted by:

- 1) compute the old standard deviation for (I,I) and (J,J):

```
STDEVOLD(I,I) = SQRT(COLD(I,I))
STDEVOLD(J,J) = SQRT(COLD(J,J))
```

- 2) compute the new standard deviation for (I,I) and (J,J):

```
STDEVNEW(I,I) = SQRT(CNEW(I,I))
STDEVNEW(J,J) = SQRT(CNEW(J,J))
```

- 3) compute correlation from old covariance:

```
COR(I,J) = COLD(I,J) / STDEVOLD(I,I) / STDEVOLD(J,J)
```

- 4) compute the new covariance:

```
CNEW(I,J) = COR(I,J) * STDEVNEW(I,I) * STDEVNEW(J,J)
```

3. Catchment area changes, number of reservoirs changes:

In this case, only the soil carryover can be adjusted and will be done according to the method in (2) above. For the reservoir carryover, the initial carryover which was read in with the parameters will become the new carryover. In other words, the elements of COLD which correspond to soil carryover will be adjusted and stored in their corresponding locations in CNEW. The remaining elements in CNEW, which correspond to reservoir carryover, will be left untouched as initial carryover read in with the new parameter set.

4. Catchment area unchanged, number of reservoirs changed:

In this case, the old soil carryover is copied from COLD to the appropriate elements of CNEW to be retained as the new carryover (note that the soil means still are deficit-adjusted). As in (3) above, the reservoir carryover elements in CNEW will remain untouched so that the new adjusted carryover becomes the initial carryover.

5. Warnings are issued if any input parameter is changed:

There are a few cases of particular concern:

- a. If the computational time interval changes, then t dependent parameters UZK, LZPK and LZSK are checked to ensure that:

$$PNEW = POLD / (OLD_INTERVAL / NEW_INTERVAL)$$

If a parameter has not been adjusted correctly, a warning is issued.

- b. A title change (card #1) may indicate that a new basin is being used and therefore the carryover saved to date may be for the wrong basin/parameter set.
- c. A change in program revision number may indicate that the carryover or something else is not compatible with previous versions.
- d. If changing from potential ET time series data to actual ET demand, the 12 monthly factors should all change from correction factors to mean demand values. Similarly, if changing from actual ET demand values to potential ET time series, the 12 factors should change. In either case, if any factor does not change, a warning is issued.
- e. If the number of reservoirs changes, then the reservoir states which have been either added or deleted (due to the change in NR) are printed along with a warning.

Punch Routine Rules: All parameters will be punched with the exact same format that the input subroutine uses to read them. Also, there will be no other differences between the original card input and the values on the cards generated by the punch card subroutine.

Figure 1. Sample Card Input For Operation SS-SAC

```

          - Column -
      5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80
-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
SS-SAC      NFDC1SSS
      North Fork American River
NFDC1      NONE      NFDC1      NFDC1SSS  NFDC1STD  NFDC1FAC
RAIM NONE  QIN    SQIN  VSQI  DFAC
      24
      6      0
      .300E+00 .900E+00 .200E+01 .270E+01 .350E+01 .460E+01 .600E+01
      .670E+01 .580E+01 .380E+01 .130E+01 .300E+00
      .213E+03 .300E+02 .720E+02 .274E+03 .400E+01 .100E+00 .700E-02
      .370E-01 .140E+02 .120E+01 .310E+00 .000E+00 .150E+00 .200E-01
      .886E+03
      2
      .100E+01 .130E+01
      .600E+00 .200E+01
      .500E+00 .100E+01
      .100E+00 .200E+00
      .500E+00 .200E+01
      .426E+02 .200E+02 .216E+02 .822E+02 .120E+01 .800E-02 .100E-02
      .700E-02 .420E+01 .360E+00 .300E-01 .000E+00 .700E-02 .100E-01
      .100E+00 .100E+00
      .213E+03 .000E+00 .720E+02 .250E+03 .200E+01 .720E+02
      .177E+02 .200E+02 .200E+02 .580E+02 .260E+01 .200E+02 .100E+01
      .300E-02
      .500E+01
  
```

Figure 2. Sample Output From Operation SS-SAC Print Parameter Routine

```

INPUT PARAMETERS & INITIAL CONDITIONS FOR OPERATION 22

STATE-SPACE SAC SMA (SS-SAC), VERSION 1.4, FOR:
    North Fork American River

NUMBER OF STATES OF SACREMENTO MODEL =      6

COMPUTATIONAL TIME INTERVAL IS  6 HOURS

NUMBER OF INITIAL SUBDIVISIONS FOR INTEGRATION =
    (time step M.A.P. value)/5.0

TIME SERIES BEING USED BY THIS OPERATION:

CONTENTS                                I.D.          TYPE          TIME INT
MEAN AREAL PRECIPITATION                NFDC1         RAIM          6 HOURS
DISCHARGE                                NFDC1         QIN           6 HOURS
SIMULATED DISCHARGE                      NFDC1SSS      SQIN          6 HOURS
SIMULATED DISCHARGE STD                  NFDC1STD      VSQI          6 HOURS
MAP VARIANCE MODIFIERS                   NFDC1FAC      DFAC          6 HOURS

PARAMETER VALUES (basin dependent):

MODIFIED-SACREMENTO MODEL SOIL PARAMETERS

UZTWM =  0.213E+03  UZFWM =  0.300E+02  LZTWM =  0.720E+02
LZFPM =  0.274E+03  LZFSM =  0.400E+01  UZK =  0.100E+00
LZPK =  0.700E-02  LZSK =  0.370E-01  ZPERC = 0.140E+02
REXP =  0.120E+01  PFREE =  0.310E+00  SIDE =  0.000E+00
ADIMP =  0.150E+00  PCTIM =  0.200E-01

CATCHMENT AREA (SQKM) =  0.886E+03

NUMBER OF ROUTING MODEL RESERVOIRS =  2

EXPONENT & COEFFICIENT PARAMETERS
OF GENERIC NON-LINEAR ROUTING RESERVOIR =
    0.100E+01 ,  0.130E+01

VARIANCE PARAMETERS OF OBSERVED DATA:

DATA          CONSTANT          COEF OF VARIATION
              STANDARD DEVIATION
M.A.P.        0.200E+01          0.600E+00
EVAPOTRANSP  0.100E+01          0.500E+00
DISCHARGE    0.100E+00          0.200E+00

COEF OF INPUT COMPONENT OF MODEL-ERROR COVARIANCE =  0.500E+00

COEF OF PARAMETER COMPONENT OF MODEL-ERROR COVARIANCE =  0.200E+01

STANDARD DEVIATION OF RAINFALL-RUNOFF
MODEL PARAMETER ESTIMATES:

UZTWM =  0.426E+02  UZFWM =  0.200E+02  LZTWM =  0.216E+02
LZFPM =  0.822E+02  LZFSM =  0.120E+01  UZK =  0.800E-02
LZPK =  0.100E-02  LZSK =  0.700E-02  ZPERC = 0.420E+01
REXP =  0.360E+00  PFREE =  0.300E-01  SIDE =  0.000E+00
ADIMP =  0.700E-02  PCTIM =  0.100E-01  ALPD =  0.100E+00
EXP =  0.100E+00

MODIFIED-SACRAMENTO MODEL INITIAL SOIL CONDITIONS:

```

UZTWC = 0.213E+03 UZFWC = 0.000E+00 LZTWC = 0.720E+02
LZFPC = 0.250E+03 LZFSC = 0.200E+01 ADIMC = 0.720E+02

DIAGONAL ELEMENTS OF INITIAL STATE COVARIANCE MATRIX:

0.313E+03 0.400E+03 0.400E+03 0.336E+04 0.676E+01 0.400E+03
0.100E+01 0.900E-05

INITIAL DISCHARGE TIME-SERIES VALUE USED = 0.500E+01

CARRYOVER FOR FORECAST COMPONENT OPERATION 22

SOIL CONTENT STATE MEAN VALUES (MM):

UZTWC = 0.213E+03 UZFWC = 0.000E+00 LZTWC = 0.720E+02
LZFPC = 0.250E+03 LZFSC = 0.200E+01 ADIMC = 0.720E+02

CHANNEL RESERVOIR CONTENT STATE MEAN VALUES (MM):

RESERVOIR 1 = 0.385E+01
RESERVOIR 2 = 0.385E+01

UPPER TRIANGULAR COVARIANCE MATRIX VALUES:

ROW 1 =
0.313E+03 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
0.000E+00 0.000E+00

ROW 2 =
0.400E+03 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
0.000E+00

ROW 3 =
0.400E+03 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00

ROW 4 =
0.336E+04 0.000E+00 0.000E+00 0.000E+00 0.000E+00

ROW 5 =
0.676E+01 0.000E+00 0.000E+00 0.000E+00

ROW 6 =
0.400E+03 0.000E+00 0.000E+00

ROW 7 =
0.100E+01 0.000E+00

ROW 8 =
0.900E-05

INITIAL DISCHARGE VALUE (CMS) = 0.500E+01

Figure 3. Sample Output From Operation SS-SAC Execution Routine

SS - SAC

JULY 2001

HYDROLOGIC RESEARCH CENTER
 12780 HIGH BLUFF DRIVE, #250
 SAN DIEGO, CA 92130-3017

BASED ON HFS SOFTWARE DEVELOPED BY
 K.P.GEORGAKAKOS, FALL 1986

RUN TITLE : North Fork American River

FORECAST COMPONENT OPERATION 22

RUN START ;03/28/1999 10
 END ;04/07/1999 4
 LAST OBS DATA;03/31/1999 4
 NOUTZ,NOUTDS,TZC: -8 0 PST

NUMBER OF UPDATE STEPS = 12
 FORECAST STEPS = 28

DATE	HOUR	MAP	ET	----- DISCHARGE IN MM/DT -----			
				PRED D	PRED STD	OBS D	EST D
03/28/1999	10:00	0.365E+00	0.568E+00	0.372E+01	0.915E+00	0.842E+00	0.107E+01
03/28/1999	16:00	0.304E+00	0.568E+00	0.797E+00	0.646E+00	0.835E+00	0.830E+00
03/28/1999	22:00	0.174E+01	0.568E+00	0.122E+01	0.495E+00	0.787E+00	0.878E+00
03/29/1999	04:00	0.185E+01	0.573E+00	0.120E+01	0.469E+00	0.752E+00	0.852E+00
03/29/1999	10:00	0.101E+01	0.573E+00	0.110E+01	0.379E+00	0.752E+00	0.857E+00
03/29/1999	16:00	0.182E+01	0.573E+00	0.113E+01	0.396E+00	0.746E+00	0.855E+00
03/29/1999	22:00	0.322E+01	0.573E+00	0.118E+01	0.546E+00	0.725E+00	0.802E+00
03/30/1999	04:00	0.293E+01	0.579E+00	0.112E+01	0.558E+00	0.718E+00	0.783E+00
03/30/1999	10:00	0.902E+00	0.579E+00	0.996E+00	0.397E+00	0.732E+00	0.805E+00
03/30/1999	16:00	0.600E+00	0.579E+00	0.968E+00	0.289E+00	0.732E+00	0.968E+00
03/30/1999	22:00	0.325E+01	0.579E+00	0.123E+01	0.552E+00	-0.999E+03	0.123E+01
MAP VARIANCE MODIFIER = 1.13							
03/31/1999	04:00	0.186E+01	0.585E+00	0.142E+01	0.707E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
03/31/1999	10:00	0.118E+01	0.585E+00	0.146E+01	0.675E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
03/31/1999	16:00	0.110E+01	0.585E+00	0.145E+01	0.613E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
03/31/1999	22:00	0.189E+00	0.585E+00	0.138E+01	0.550E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/01/1999	04:00	0.522E-01	0.590E+00	0.129E+01	0.486E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/01/1999	10:00	0.140E+00	0.590E+00	0.122E+01	0.441E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/01/1999	16:00	0.279E+00	0.590E+00	0.118E+01	0.415E+00	-0.999E+03	0.142E+01

MAP VARIANCE MODIFIER = 1.13

04/01/1999	22:00	0.600E-01	0.590E+00	0.115E+01	0.396E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/02/1999	04:00	0.481E-01	0.596E+00	0.111E+01	0.379E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/02/1999	10:00	0.481E-01	0.596E+00	0.109E+01	0.366E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/02/1999	16:00	0.136E+00	0.596E+00	0.107E+01	0.356E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/02/1999	22:00	0.891E+00	0.596E+00	0.110E+01	0.367E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/03/1999	04:00	0.850E+00	0.602E+00	0.113E+01	0.389E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/03/1999	10:00	0.429E+00	0.602E+00	0.114E+01	0.390E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/03/1999	16:00	0.512E+00	0.602E+00	0.113E+01	0.379E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/03/1999	22:00	0.156E+01	0.602E+00	0.117E+01	0.411E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/04/1999	04:00	0.154E+01	0.607E+00	0.123E+01	0.462E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/04/1999	10:00	0.993E+00	0.607E+00	0.124E+01	0.471E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/04/1999	16:00	0.267E+01	0.607E+00	0.132E+01	0.531E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/04/1999	22:00	0.633E+01	0.607E+00	0.160E+01	0.876E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/05/1999	04:00	0.427E+01	0.613E+00	0.182E+01	0.108E+01	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/05/1999	10:00	0.192E+01	0.613E+00	0.181E+01	0.991E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/05/1999	16:00	0.143E+01	0.613E+00	0.169E+01	0.818E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/05/1999	22:00	0.214E+01	0.613E+00	0.162E+01	0.715E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/06/1999	04:00	0.171E+01	0.619E+00	0.158E+01	0.672E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/06/1999	10:00	0.981E+00	0.619E+00	0.150E+01	0.614E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/06/1999	16:00	0.117E+01	0.619E+00	0.143E+01	0.555E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/06/1999	22:00	0.219E+01	0.619E+00	0.144E+01	0.568E+00	-0.999E+03	0.142E+01
MAP VARIANCE MODIFIER = 1.13							
04/07/1999	04:00	0.179E+01	0.624E+00	0.146E+01	0.598E+00	-0.999E+03	0.142E+01